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TENSILE/COMPRESSIVE AND FLEXURAL PROPERTIES OF NATURAL/SYNTHETIC HYBRID FIBRE METAL LAMINATE COMPOSITES

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ABSTRACT

The mechanical properties of any material are the most important factor considered in producing components in the structure; therefore, the reinforced fibre-metal laminate composites can be in automotive and aerospace industries and other local manufacturing companies, due to their high strength and stiffness. The study investigates the tensile, compressive and flexural properties of the fabricated composites (kenaf and flax composites). The two composites were fabricated in a mould using a traditional method (hand lay-up) cured at room temperature and post-cured in an oven at 80ºC for 3 hours. The properties test of the composites was carried out using a universal testing machine (UTM). Five samples were cut from each sample based on the ASTM standard for tensile, compression, and flexural test. The result of the test shows a decrease in the properties of pure synthetic fibre metal laminates. Flax composite is 14.22% and 22.03% greater than kenaf composite and 25.64% lower than it in terms of tensile, compressive and flexural strength respectively. Based on the strength obtained in the study, the composites can be used in automobile and aerospace industries for developing different components even in the interior and exterior sections of aerospace.

Keywords: Composite; compression; flexural; tension; universal testing machine.

1. INTRODUCTION

The use of natural fibres to construct or produce a structure began before recorded history. It is obtained from vegetables, animals and or mineral sources, and then converted into fabrics and clothes. The fibre finds application from different researchers due to its availability, less cost, eco-friendly and lightweight. The fibre has good properties that make it useful now a day such as abrasion resistance, elasticity, absorbency, strength, length, etc. Among the natural fibre used are kenaf, flax, cotton, hemp, coir, wool, jute, kapok, ramie, and abaca sisal, among others. Bast fibres are the most commonly used fibre since it is occurring in the inner bast tissue in the stem of the plant and it is made up of overlapping cells; such as hemp, ramie, jute, flax etc. The natural fibres have an affinity for water in gaseous and in liquid form, which resulted in swelling of the fibre [1,2,3,4,5].

Synthetic fibres are fibres made by man, mostly made from petrochemical. Mostly contain polymers from monomers, which include acrylics, nylon, polypropylene, polyurethane, etc. The fibres are elastic, durable, resist wear and tear, soft, last longer, cheaper and stronger than natural fibre. But synthetic fibre has some health issues, like itching, less water absorption and can catch fire easily. Carbon and glass fibres are some examples of synthetic fibre [6].

Therefore, the combination of natural fibres with synthetic fibres resulted in a composite with remarkable properties such as stiffness, strength, resistance to crack fatigue growth, and water absorption, it also creates a good fabrication atmosphere. Bandaru *et al.* [6] were among the researchers who studied the hybridisation of synthetic and natural fibres, whereby the effect of hybridisation on the ballistic impact behaviour of hybrid composite armours was studied. Likewise, Mohammed *et al.*, [1] have studied the mechanical properties of the hybridisation between carbon fibre and flax.

To utilize the advantages of fibre metal laminates to be used in different components of the machines, it is necessary to know the properties of the type of FML composites. Fibre-metal laminate (FML) composite consists of reinforced fibre and metal alloy bonded by a polymer matrix. It has the advantage of reinforced fibre, metal alloy and the matrix. It is used in various industries; due to it is high performance as a component in constructing different structural components[7,8].

The main objective of the study is to compare the tensile, compressive and flexural strength of the two composites of fibre metal laminate composites. A universal testing machine was used in the mechanical properties test with a crosshead speed of 0.5mm/min for the entire test carried out using the machine. The natural/synthetic composites will have excellent properties that almost compete with some types of synthetic composites, especially glass fibre composite. The study of the composite consists of a natural fibre (flax and kenaf), a synthetic fibre (carbon fibre), and sheets of aluminium alloy 2024-T3 that are used at the front and rear face of the reinforced composites bonded together using an epoxy resin/hardener. The hybridisation yield a composite that is free from moisture absorption, excellent fatigue resistant, free from corrosion and good stiffness and strength with good impact strength [9,8].

2. MATERIALS AND METHODS

The reinforced fibres (natural/synthetic) and aluminium alloy were cut 400mm x 400 mm x 4 based on the size of the mould. The epoxy resin & hardener were mixed in a ratio of 2:1 respectively. The composites were fabricated and allowed to cure for a day and allow curing again for a short time after removing from the mould.

Table 1 shows the material layer used in the two composites with their corresponding thickness in each composite.

Table 1: Materials used with their Thickness

Composites	**Items**	**Thickness (mm)**	**Number of Layers**
	Carbon Fibre	0.25	4
Composite 1	Kenaf Fibre	0.7	2
	Aluminium Alloy	0.4	2
	Carbon Fibre	0.25	4
Composite 2	Flax Fibre	0.7	2
	Aluminium Alloy	0.4	2

From Table 1 each composite was fabricated with two sheets of aluminium alloy in the front and rear face. Composite 1 contains two layers of kenaf fibre and four layers of carbon fibre, whereas composite 2 contains two layers of flax fibre and four layers of carbon fibre.

The composites undergo three main common types of mechanical tests that comprise tensile, compression and flexural tests. The tests were carried out using the universal testing machine (UTM) of 100kN. For all the tests five samples were cut from the main composites and the tests were carried out according to ASTM standard of each test and the average value of each test was evaluated.

The tensile test of the FML composites was conducted according to the ASTM standard (D3039/D3039M-14, 2014) [10]. Five samples from each composite were cut 120mm x 20mm x 4mm; the samples were placed in between the two tensile fixtures and locked for the test, whereas the average values of each composite were calculated. The crosshead speed of the machine was kept at 0.5mm/min during the test.

The compression test of the laminate composites was conducted according to the ASTM standard (D3410/D3410-16, 2016)[11] in which five samples were cut in the square shape of 12.75mm x 12.75mm x 4mm, and the crosshead speed was kept at 0.5mm/min during the test. The samples were placed in between the two compression platen and compressed till failure. The results obtained were averaged for each composite.

The flexural test was conducted according to ASTM standard (ASTM, 2007), [12]also five samples were cut according to the standard that uses a formula reported by Ning *et al.* [13] as indicated in Equation (1) to find the length of the cut sample:

$$L = 16d + 20\% \text{ of the length} \qquad (1)$$

Where d is the width (4mm) of the sample specimen and L is the sample length.

Therefore the samples were cut 77mm x 20mm x 4mm. The test uses a three-point bending method, whereby the crosshead speed was maintained at 0.5mm/min.

3. RESULT AND DISCUSSION

The average results of five samples cut from each composite were obtained after undergoing the mechanical test. The tensile, compression and flexural test results were presented in Figure 1 where loads of each test and extension are presented in the characterisation curves.

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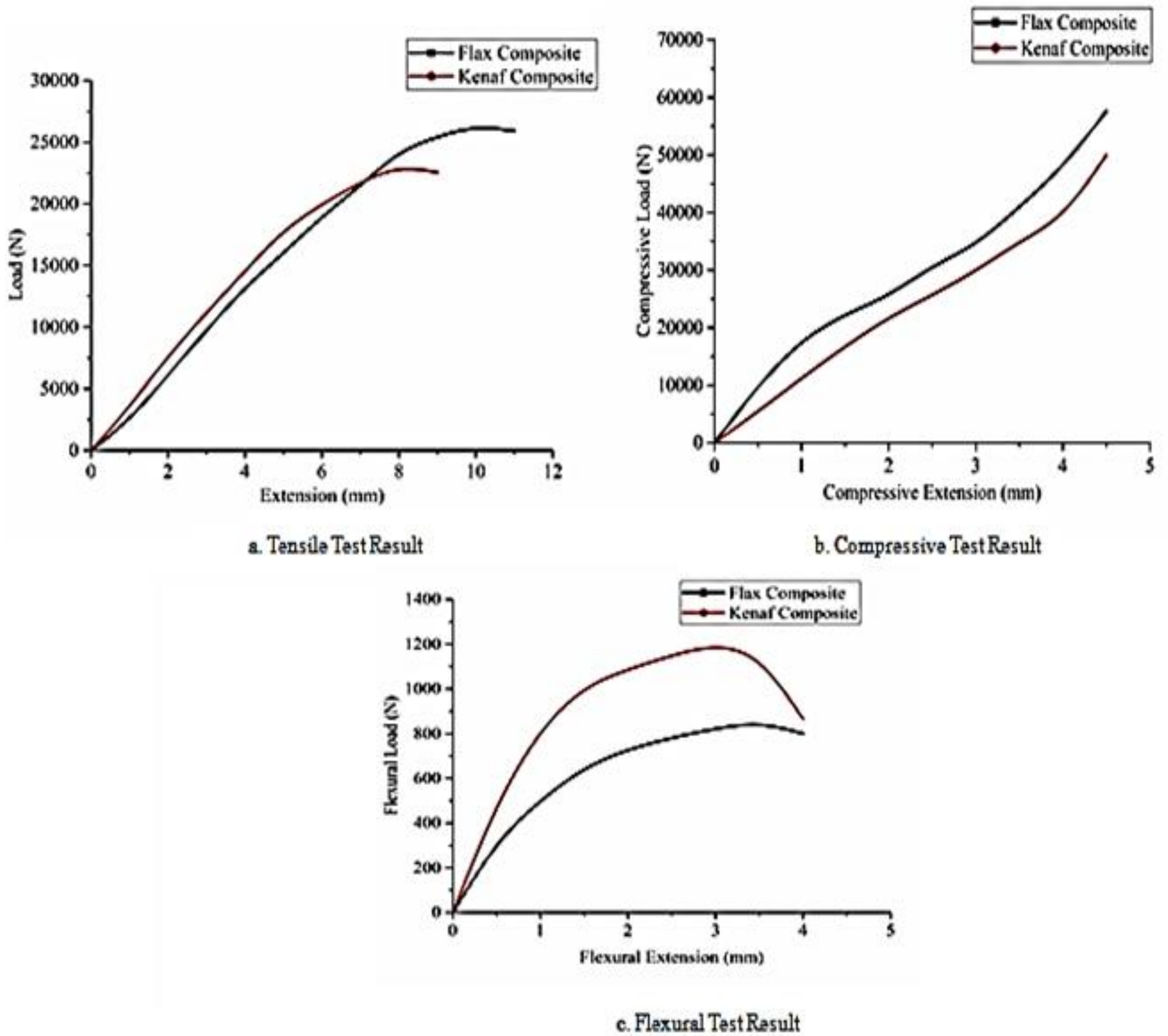
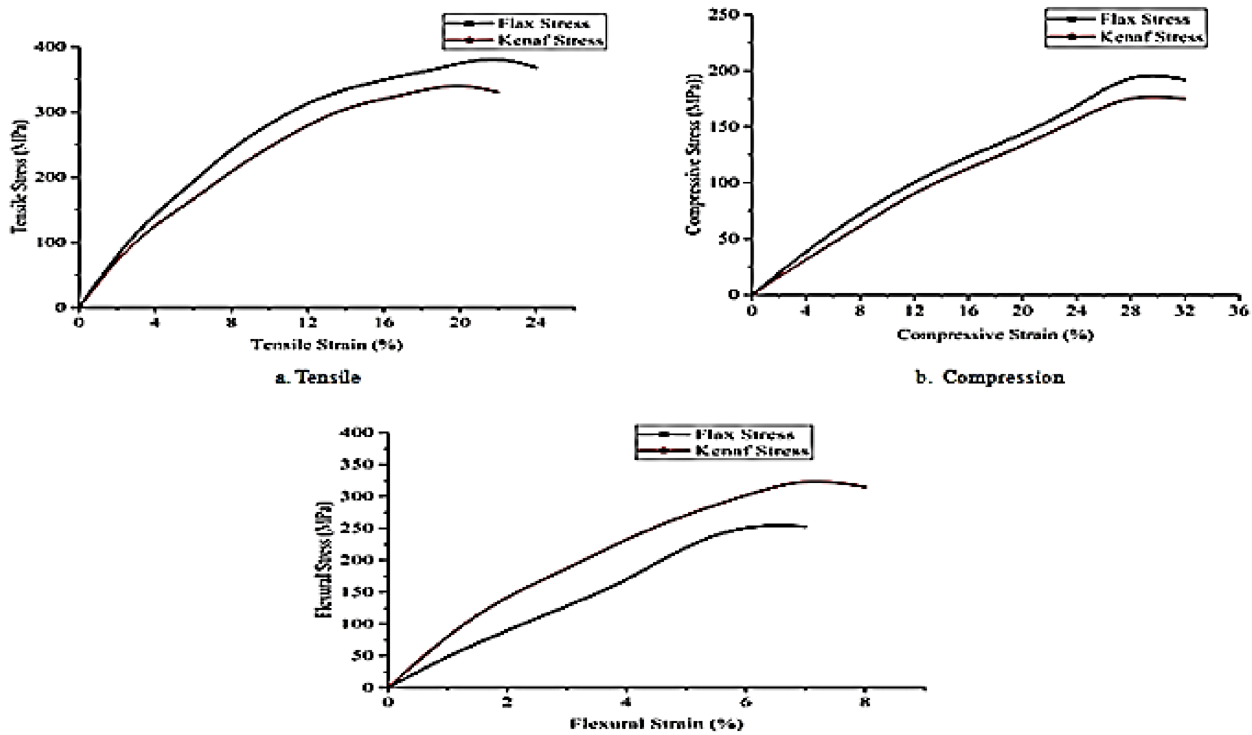


Figure 1: Mechanical Test Results

The result obtained from the characterisation curve of all the three properties considered in the investigation for the two composites shows that an increase in the extension resulted to increase of load till a certain level, where the maximum extension was attained, and then the samples fell and the load dropped. Differences found on the composites depend on the materials used in fabricating the composite.

The characteristic of the curve observed in this study for the tensile and flexural properties test was reported by & Tamilarasan *et al.* [1,14].In their study they have used synthetic fibre metal laminates. The result obtained was a little bit higher than the result obtained for this hybrid composite. Also Zikre and Bhatt [15] have reported on the tensile and compressive properties of natural fibres laminates and also a studied on the glass fibre with bamboo natural fibre, where the result obtained was less than the result obtained in this investigation.

The results obtained from the mechanical test were used and analysed to obtain the stresses and percentage strain of the properties as in Figure 2 and the results were used to calculate the strength of each property.



c. Flexural

Figure 2: Stress/Strain Curve of the Mechanical Properties of the two composites

The tensile, compressive and flexural strength were computed from a different analysis of the test results. The flexural strength was obtained using Equation (2) as reported by Al-Darwish *et al.* [16]

$$\delta = 3\omega I / 2bd^2 \quad (2)$$

Where: δ = flexural strength (MPa)
ω = maximum load applied to the specimen (N)
I = distance between the two supports (mm)
b = width of the specimen (mm)
d = height of the specimen (mm)

Table II shows the strength of the two composites under investigation, where the flax composites show higher properties.

Table II: Strength of the two Composites

Composites	Tensile Strength (GPa)	Compressive Strength (GPa)	Flexural Strength (GPa)
Composite 1	3.80	0.46	0.39
Composite 2	4.43	0.59	0.29

The interfacial cohesion that exists between the fibre and the polymer increases the tensile strength of the composites as reported in Mendez *et al.*[17], Mutjé *et al.* [18] and Vilaseca *et al.* [19]. In the compressive stress test, a crack noise and metal destruction were noticed due to adhesive de-bonding between the fibres and the polymer matrix. This nature was reported by Remmers and De Borst [20]. Also, the good interface between fibre and the polymer improved the flexural strength of the two composites; the interface produces a good stress transfer between the fibre and the polymer matrix as also reported by Tawakkal et al [21].The delamination was observed in the entire properties test before failure as observed in the work by Rajkumar *et al.* [22]and Reyes and Kang [23]. The mechanical test conducted on the hybrid composites shows that the hybrid of natural with synthetic fibre can be used to replace the synthetic fibre due to the excellent properties obtained.

4. CONCLUSION

The tensile, compressive and flexural strength of the composites were investigated as stated in the objectives. Based on the result obtained from the properties test results the study shows that, the two composites is capable to be used as a structural component in the near future due to its resistant to corrosion, lightweight material, high strength and stiffness and a flame resistant properties. The properties tests result indicates that flax composite presents good properties result than the kenaf composite more especially on the tensile and compressive properties. Almost, the two composites considered show the same properties with the same behaviour during the test, but with a little or no differences. The fireproof behaviour of flax composite indicates that the properties of the flax natural fibre were a little bit similar to mechanical properties of synthetic fibres. With the abundant of natural fibre and less cost, its hybrid with synthetic fibre will in near future replace the metals due to its low cost, properties after treated and it is abundant in nature, required less fabrication process.

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